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## Should the finger pressure be well distributed across the seam in seam bowling? A problem of precession and torque

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### Abstract

In seam bowling, the first two fingers are supposed to impart equal amounts of back-spin to the ball. As the rotating arm of the bowler and the backspin of the ball have different senses (clockwise vs. counterclockwise), the spin axis moves rapidly from one hemisphere to the other, thereby crossing the seam, when finger torque is imparted onto the ball. It is shown in this study analytically, that the rapidly precessing spin axis approaches the torque vector, but reaches the torque vector only at large times. From the experimental data, the spin and torque vectors are approximately 10-15° apart when releasing the ball in seam bowling. If the spin axis is not exactly at the pole of the ball, i.e. perpendicular to the seam, then the seam wobbles by twice the angle between spin and torque vectors. It is therefore advisable to have the finger centre of pressure slightly off seam by 10-15°.

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## 1. Introduction

According to Woolmer and Noakes [1], in seam bowling, “the first two fingers rest on either side of the seam” ([1], p. 251) and the “first and second fingers impart equal amounts of back-spin to the ball” ([1], p. 253, figure legend). This seems obvious when considering that the seam of a cricket ball wobbles if the spin axis is not perfectly perpendicular to the plane of the seam (Figure 1). If the finger pressure was not well distributed across the seam but rather off the seam, then one finger would contribute more spin and the spin axis would be tilted with respect to the plane of the seam (Figure 2).

The paradox in fast bowling is that the arm rotates clockwise (side view of a bowler delivering the ball to the right) as fast as possible in order to achieve a high linear velocity of the ball, whereas the spin imparted onto the ball is counter clockwise (backspin). This would in theory mean that once the fingers impart a torque to the ball, the negative (clockwise) angular velocity of the rotating arm would reduce to zero before the backspin takes over resulting in a positive (counter clockwise) angular velocity. This is only possible if the angle between the initial angular velocity vector and the torque vector was  $\pi$  ( $90^\circ$ ). In all other cases the angular velocity vector precesses and moves into the torque vector by rotating about the centre of mass (Figure 3),

$$p = \dot{\phi} = \sin \theta \frac{T}{\omega I} \quad (1)$$

Where  $p$  and  $\dot{\phi}$  are the angular precession velocity,  $T$  is the torque,  $\omega$  is the angular velocity,  $I$  is the moment of inertia,  $\phi$  is the angle of the precessing  $\omega$  vector, and  $\theta$  is the angle between  $T$  and  $\omega$  ( $\phi + \theta = \pi/2$ ).

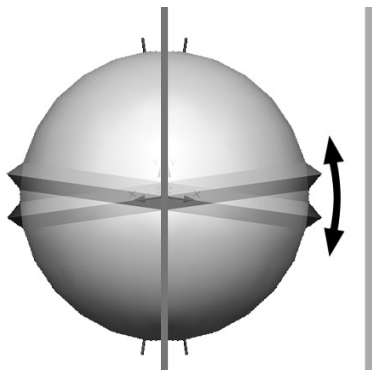


Fig. 1. Seam wobble

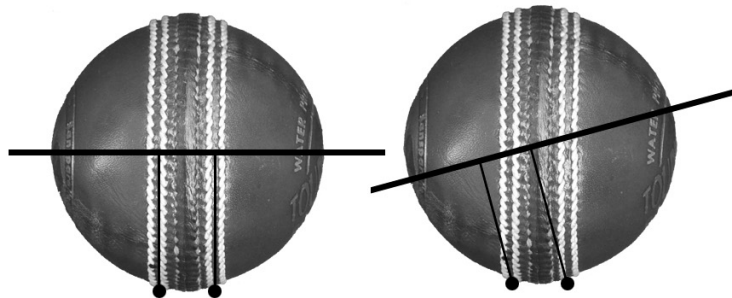


Fig. 2. Equal (left) and unequal (right) contributions of the fingers to the spin and their effect on the tilt of the spin axis

## 2. Mathematical analysis

From Eqn (1), if  $\theta = 0$  or  $\pi$ , the angular velocity  $p$  of the precession is zero. If  $0 < \theta < \pi$ , then  $p > 0$  and the spin vector  $\omega$  precesses into the torque vector  $T$ . The closer  $\theta$  tends to zero, the smaller  $p$  and the slower the spin vector  $\omega$  closes in towards the torque vector  $T$ . Figure 4 shows this asymptotic behaviour of angle  $\theta$ . Therefore,  $T$  and  $\omega$  vectors have identical direction only if time approaches infinity. From Eqn (1) and Figure 4, the larger  $T$  and the smaller the angular impulse  $L$ , i.e.  $\omega I$ , the denominator in Eqn (1), the faster  $\omega$  approaches  $T$ .

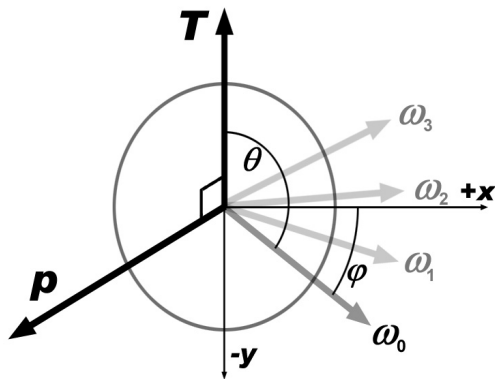


Fig. 3. Precession of the spin axis;  $\omega$  = vector of the spin rate;  $\omega_0 \dots \omega_3$  = precessing spin vector;  $T$  = torque vector;  $p$  = vector of the angular velocity of the precession;  $\theta$  = angle between  $T$  and  $\omega$ ;  $\phi$  = angle of the precessing  $\omega$  vector;  $+x, -y$  = coordinate system ( $xp$  = seam plane).

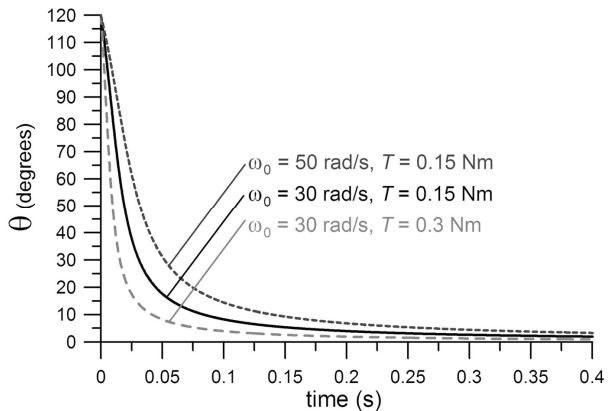


Fig. 4. angle  $\theta$  (between torque and spin vectors) against time;  $\omega_0$  = initial spin rate;  $T$  = constant torque imparted onto the ball.

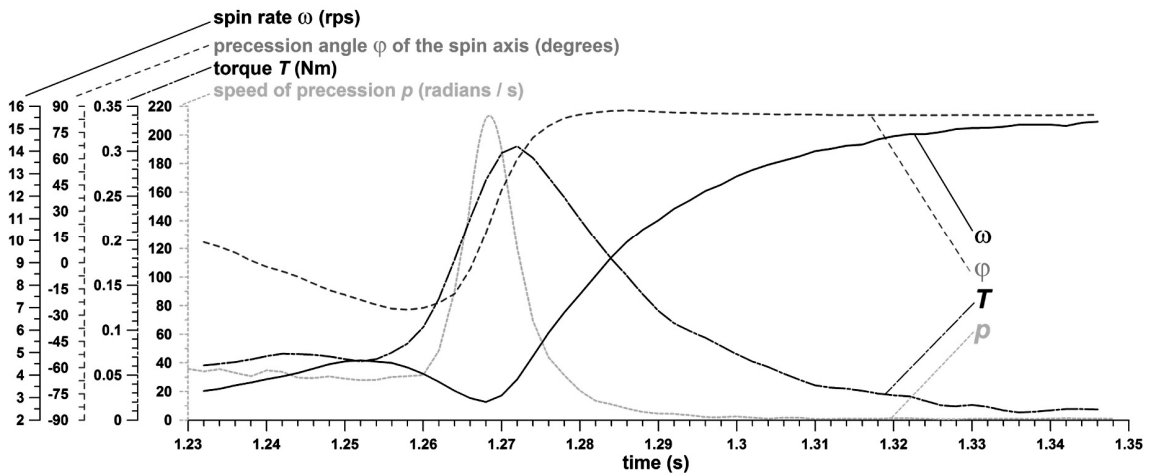


Fig. 5. Parameters (spin rate, precession angle and rate, torque) against time; rps = revolutions per second.

### 3. Experimental procedure

A bowler delivered four seam bowls with the smart cricket ball developed by Fuss and Smith [2, 3]. The ball is instrumented with three high-speed gyros, a data logger and a battery. The triaxial spin rate data were collected at 500 Hz from the beginning of the delivery, to the impact on the pitch. The raw data were processed with the smart cricket ball software [4].

#### 4. Results

The results are shown in Figures 5 and 6 and Table 1. The spin rate  $\omega$  decreased once the finger torque  $T$  increased (at  $t = 1.252$  in Figure 5) and reached its minimum at maximal precession rate  $p$ . The precession angle  $\phi$  of the spin axis increased from  $-30^\circ$  to almost  $+90^\circ$ , thereby crossing the plane of the seam.

Figure 6 shows the spin vector closing in on the torque vector, in top view (intersection of vector and ball surface projected on the plane of the seam). From Figure 6 and Table 1 it becomes evident that the spin vector did not reach the torque vector and an angle of  $10\text{--}15^\circ$  remained between the two vectors.

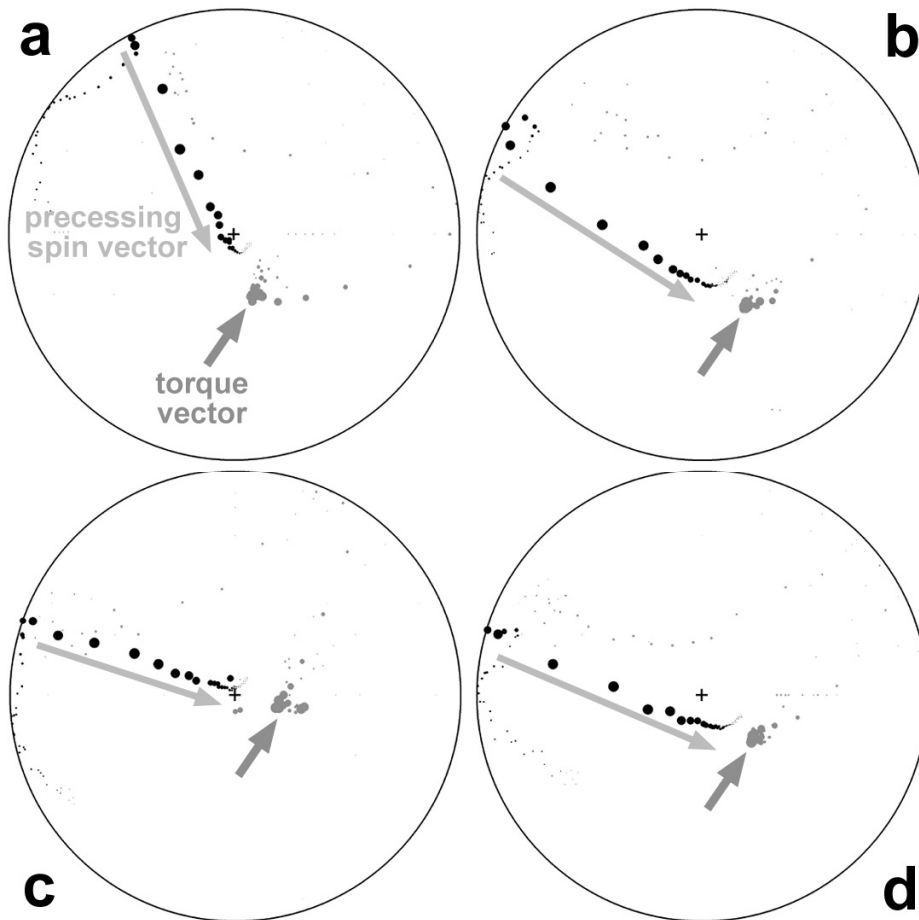


Fig. 6. Spin and torque vectors in top view; the intersection point between a vector and the ball's surface is projected onto the plane of the seam; + = pole of the ball, where the spin axis at release should be ideally located in order to avoid seam wobble; subfigures a-d refer to delivery number 1-4 in Table 1.

## 5. Discussion

Analytical (Figure 4) and experimental (Figure 6) data lead to the same results: the precessing spin axis approaches the position of the torque vector asymptotically but does not entirely reach that position in the given time during which the torque is imparted onto the ball. This means, if the torque vector is exactly at the pole of the ball, resulting from equal pressure and friction force distribution of the fingers across the seam, then the spin axis would still be off the pole and lead to seam wobble. The spin axis would approach the pole quicker if more spin was imparted onto the ball. The constraint is, however, the short time period available for imparting the spin (50-70 ms) and the distinct shape of the torque spike. Even when simulating a constant torque with the same conditions taken from the experimental data (Figure 4 and Table 1), it takes 50 ms for closing the gap between spin and torque vectors to  $10^\circ$ .

An alternative approach for avoiding seam wobble would be to still have the fingers on either side of the seam but have the finger centre of pressure slightly off seam, such that the torque vector is about  $10$ - $15^\circ$  off the pole. This was, surprisingly, applied in deliveries 1 and 3 (Figure 6ac; Table 1). If, however, the fingers do not move parallel to the seam when imparting the torque, but rather move at a slight angle to the seam, then the path of the precessing spin axis does not approach the pole of the ball but moves past it laterally (cf. deliveries 2 and 4 in Figure 6bd).

The principle of the spin axis moving from one hemisphere to the other, thereby crossing the seam at high precession speed, occurs only in fast bowling. In contrast to that, in spin bowling, the spin axis of the rotating arm continues seamlessly into the spin axis of the rotating hand when imparting torque onto the ball [2].

The experimental results presented are based on a single bowler only. These results serve to illustrate the principles outlined in the mathematical analysis as well as to validate the conclusions drawn in the analysis section.

Further research with the smart cricket ball needs to be carried out in order to address the following questions:

- Does the principle of the first two fingers resting on either side of the seam [1] really impart equal amounts of back-spin to the ball [1], by having the torque vector exactly at the pole; or is one finger more dominant such that the torque vector is generally off the pole, thereby enabling the spin axis to move into the pole?
- Does placing the fingers asymmetrically across the seam lead to more spin precision, by having the torque vector off the pole and the spin axis vector exactly at the pole?

Table 1. Parameters of 4 deliveries (rps = revolutions per second).

no. of delivery	1	2	3	4
maximal spin rate (rps)	15.25	15.75	16.5	19.5
initial precession angle $\varphi$ of the spin axis	$-29^\circ$	$-30^\circ$	$-18^\circ$	$-30^\circ$
terminal precession angle $\varphi$ of the spin axis	$+88^\circ$	$+78^\circ$	$+89^\circ$	$+84^\circ$
position angle of the torque vector	$+73^\circ$	$+68^\circ$	$+79^\circ$	$+72^\circ$
maximal torque (Nm)	0.313	0.318	0.309	0.379
maximal precession rate (rad/s)	210	230	137.5	245

## 6. Conclusions

Both analytical simulation data and experimental data collected with a smart cricket ball confirm that the seam bowling technique stated by Woolmer and Noakes (2008; that the “*first and second fingers impart equal amounts of back-spin to the ball*”) leads to seam wobble, and it would be advantageous if the pressure centre would be approximately 10-15° of the seam in order to avoid seam wobble.

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